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Yang

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(54) **MOBILE COMMUNICATION DEVICE**

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H04B 1/3827 (2015.01)

(52) **U.S. Cl.**
CPC ***H04B 1/3838*** (2013.01)

(58) **Field of Classification Search**
CPC H04B 1/3838
USPC 455/78, 280, 550.1; 343/720
See application file for complete search history.

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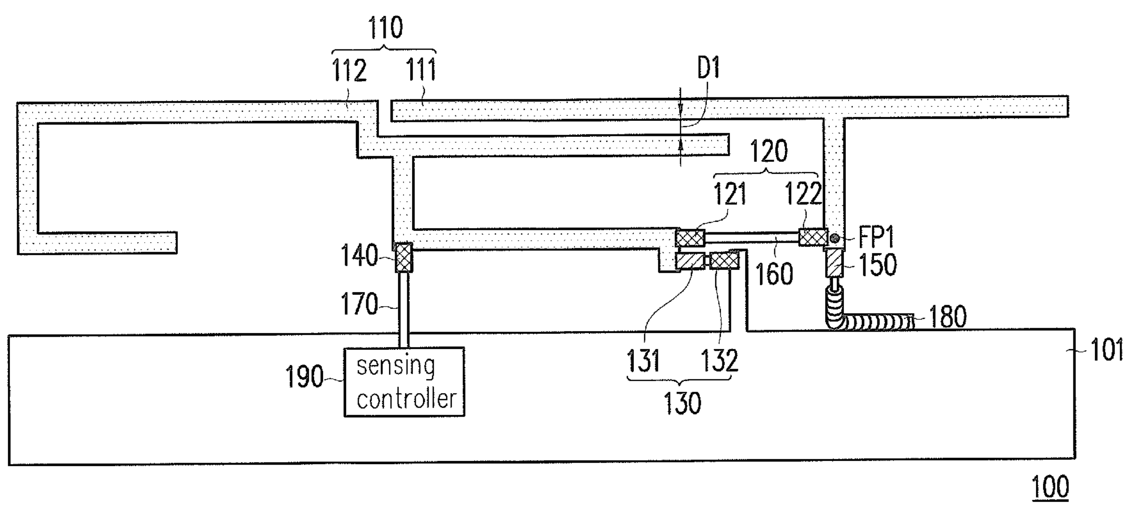
(57) **ABSTRACT**

A mobile communication device including an antenna element, a low-frequency blocking element, a first isolation circuit, a second isolation circuit and a high-frequency blocking element is provided. The antenna element converts a radio-frequency signal into an electromagnetic wave and generates a sensing signal in response to a proximity of an object. The antenna element includes a radiation portion and a parasitic portion which are spaced by a coupling gap. The low-frequency blocking element transmits the radio-frequency signal to the radiation portion. The first isolation circuit and a connection element are connected in series between the radiation portion and the parasitic portion, and the first isolation circuit blocks the radio-frequency signal. The second isolation circuit is electrically connected between the parasitic portion and a ground plane, and blocks the sensing signal. The high-frequency blocking element transmits the sensing signal from the antenna element to a sensing controller through a metal line.

7 Claims, 3 Drawing Sheets



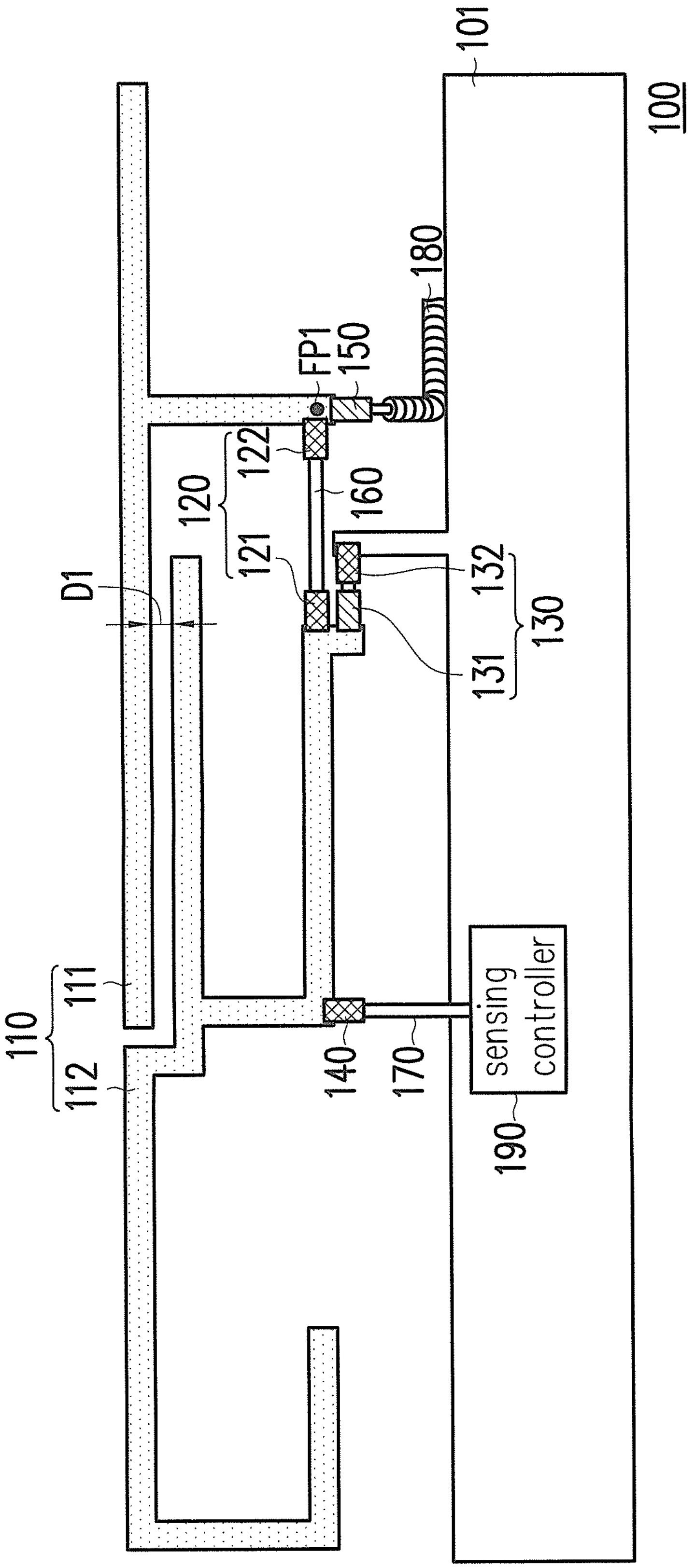

101
100
180
FP1
150
122
120
160
121
132
130
131
D1
110
111
112
140
170
sensing controller
190

FIG. 1

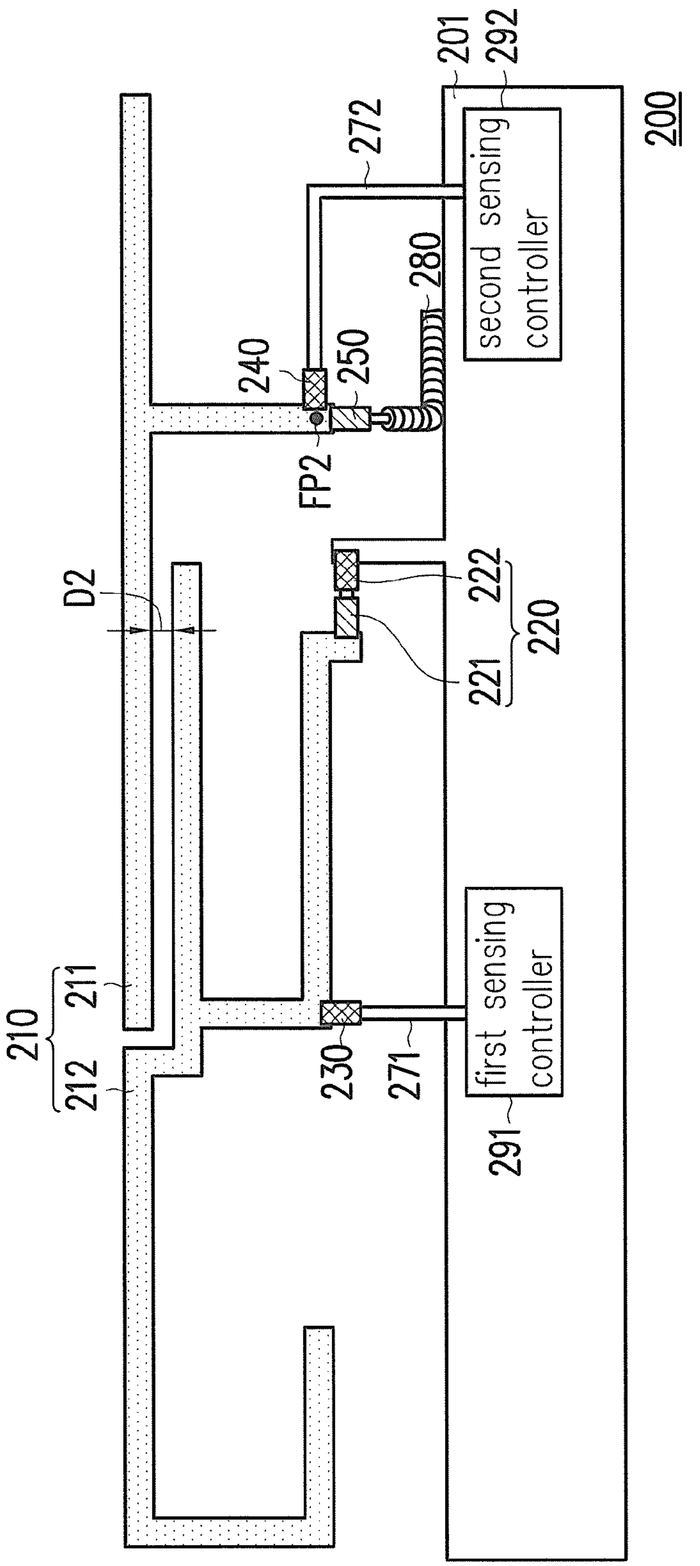

200
201
292
second sensing controller
272
280
240
250
FP2
222
221
220
D2
210
211
212
230
271
first sensing controller
291

FIG. 2

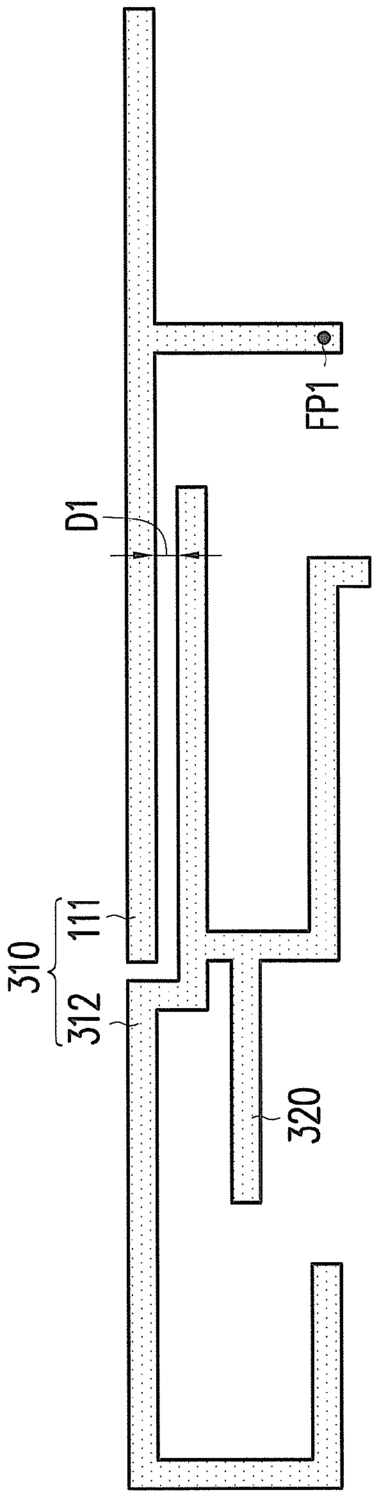


FIG. 3

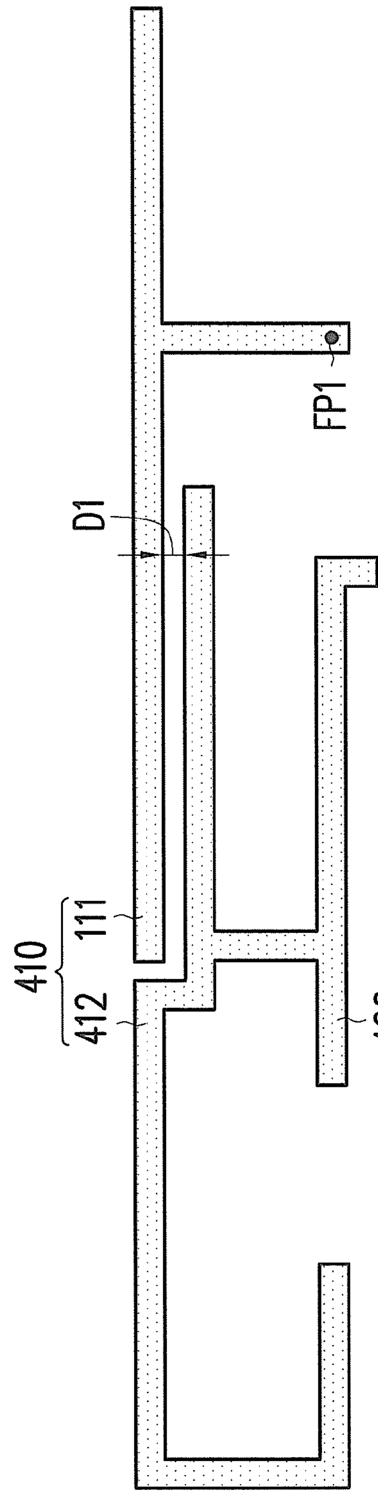


FIG. 4

MOBILE COMMUNICATION DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 102146904, filed on Dec. 18, 2013. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a mobile communication device, and more particularly, relates to a mobile communication device capable of sensing by using an antenna element.

2. Description of Related Art

A proximity sensor is disposed in most of the existing mobile communication devices in order to prevent an electromagnetic wave radiated by an antenna element from endangering human health. Generally, the proximity sensor includes a sensing electrode and a sensing controller. Further, the sensing electrode is often placed next to the antenna element in the existing mobile communication devices, so as to satisfy demands of miniaturization for the mobile communication devices. Further, when the human body is near the antenna element, the sensing controller may output a control signal for reducing an output power of a radio-frequency module, so as to reduce absorption of the electromagnetic wave by the human body.

However, a radiation characteristic of the antenna element is usually influenced when a larger area of the sensing electrode is placed next to the antenna element, such that a communication quality of mobile communication device is reduced accordingly.

SUMMARY OF THE INVENTION

The invention is directed to a mobile communication device, which combines an antenna element and a sensing electrode as one by using an isolation circuit and a blocking element. Accordingly, the antenna element includes the function of the sensing electrode and reduces influences caused by the sensing electrode to the antenna element.

A mobile communication device of the invention includes an antenna element, a low-frequency blocking element, a first isolation circuit, a second isolation circuit and a high-frequency blocking element. The antenna element is provided with a capacitive sensing function and an antenna function, and the naming of the low-frequency blocking element and the high-frequency blocking element is defined for better understanding of their functions. For example, a behavior of a capacitance change in the capacitive sensing is of low-frequency as compared to the antenna function, and a behavior of a resonant current distribution in the antenna function is of high-frequency as compared to the capacitance sensing. The low-frequency and high-frequency blocking elements allow the antenna element to include both functions without having them influencing each other. In addition, the antenna element is equivalent to a capacitance sensing element. For example, the antenna element may be regarded as a larger sheet of metal plate, and a capacitance of the antenna element changes when an object is near to thereby generate a sensing signal. In addition, the antenna element includes a radiation portion and a parasitic portion which are spaced by a coupling gap. The low-frequency blocking element is electrically connected to the radiation portion, and configured to block the sensing signal from flowing into a feeding point of the radiation portion. In application, the feeding point of the radiation portion is electrically connected to a radio-frequency module through a coaxial cable, such path generates a large capacitance, and the antenna element cannot sense a proximity of the object if the sensing signal is not blocked by using the low-frequency blocking element. In addition, the low-frequency blocking element does not block the radio-frequency signal, so that the radio-frequency signal can still be transmitted to the feeding point of the radiation portion. The first isolation circuit and a connection element are connected in series between the radiation portion and the parasitic portion, and the first isolation circuit is configured to block the radio-frequency signal and allow the sensing the sensing signal to pass through. The second isolation circuit is electrically connected between the parasitic portion and a ground plane, and the second isolation circuit is configured to block the sensing signal from passing through and transmit the radio-frequency signal. The high-frequency blocking element is electrically connected between the parasitic portion and a metal line to block the radio-frequency signal from flowing into a sensing controller and transmit the sensing signal from the antenna element to the sensing controller through the metal line.

In another embodiment, a mobile communication device of the invention includes an antenna element, a low-frequency blocking element, an isolation circuit, a first high-frequency blocking element and a second high-frequency blocking element. The antenna element includes a radiation portion and a parasitic portion which are spaced by a coupling gap. The parasitic portion generates a first sensing signal in response to a proximity of an object, and the radiation portion generates a second sensing signal in response to the proximity of the object. The low-frequency blocking element is electrically connected to the radiation portion, and configured to block the sensing signal from flowing into a feeding point. In application, the feeding point is electrically connected to a radio-frequency module through a coaxial cable. Such path generates a large capacitance, and the antenna element cannot sense a proximity of the object if the sensing signal is not blocked by using the low-frequency blocking element. In addition, the low-frequency blocking element does not block the radio-frequency signal, so that the radio-frequency signal can still be transmitted to the feeding point of the radiation portion. The isolation circuit is electrically connected between the parasitic portion and a ground plane. In addition, the isolation circuit is configured to block the first sensing signal and transmit the radio-frequency signal. The first high-frequency blocking element is electrically connected between the parasitic portion and a first metal line, and transmits the first sensing signal to a first sensing controller through the first metal line. The second high-frequency blocking element is electrically connected between the radiation portion and a second metal line, and transmits the second sensing signal to a second sensing controller through the second metal line.

Based on the above, in addition to the function of the wireless transmission, the antenna element of the invention may also be used as the sensing element of the sensing controller. In addition, the high-frequency blocking element is further disposed on the parasitic portion of the antenna element in the invention, such that the metal line for connecting to the sensing controller may be routed from at least one side of the antenna element. Accordingly, the radio-frequency signal may be blocked from flowing into the sensing controller through the metal line, so as to prevent original characteristics of the antenna element from being influenced.

To make the above features and advantages of the disclosure more comprehensible, several embodiments accompanied with drawings are described in detail as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIG. **1** is a schematic structural view illustrating a mobile communication device according to an embodiment of the invention.

FIG. **2** is a schematic structural view illustrating a mobile communication device according to another embodiment of the invention.

FIG. **3** and FIG. **4** are schematic structural views respectively illustrating an antenna element according to an embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

FIG. **1** is a schematic structural view illustrating a mobile communication device according to an embodiment of the invention. As shown in FIG. **1**, a mobile communication device **100** includes an antenna element **110**, a first isolation circuit **120**, a second isolation circuit **130**, a high-frequency blocking element **140** and a low-frequency blocking element **150**. The antenna element **110** includes a radiation portion **111** and a parasitic portion **112**.

The radiation portion **111** has a feeding point FP**1**, and the radiation portion **111** and the parasitic portion **112** are spaced by a coupling gap D**1**. Further, the first isolation circuit **120** and a connection element **160** are connected in series between the radiation portion **111** and the parasitic portion **112**. The second isolation circuit **130** is electrically connected between the parasitic portion **112** and a ground plane **101**. The high-frequency blocking element **140** is electrically connected between the parasitic portion **112** and a metal line **170**. The low-frequency blocking element **150** is electrically connected to the radiation portion **111**.

In operation, the antenna element **110** may convert a radio-frequency signal into an electromagnetic wave, so that the mobile communication device **100** may perform a wireless transmission through the antenna element **110**. For instance, in an embodiment, the radiation portion **111** is electrically connected to a coaxial cable **180** through the low-frequency blocking element **150**. The coaxial cable **180** is configured to transmit the radio-frequency signal generated by a radio-frequency module in the mobile communication device **100**. Further, the radio-frequency signal transmitted by the coaxial cable **180** passes through the low-frequency blocking element **150** to be transmitted to the feeding point FP**1** of the radiation portion **111**, and the antenna element converts the radio-frequency signal into the electromagnetic wave to be transmitted.

It should be noted that, for the radio-frequency signal (e.g., an antenna current), the first isolation circuit **120** and the high-frequency blocking element **140** form a broken circuit (i.e., open circuit) for blocking the radio-frequency signal (e.g., the antenna current) from passing through, and the second isolation circuit **130** forms a short circuit for allowing the radio-frequency signal (e.g., the antenna current) to pass through. Accordingly, the radiation portion **111** generates at least one high-frequency resonant mode under excitation of the radio-frequency signal. For example, in the embodiment of FIG. **1**, a shape of the radiation portion **111** is a T-shape, and the radiation portion **111** is essentially a dual-band monopole antenna. Therefore, the antenna element **110** may generate two high-frequency resonant modes through the radiation portion **111**.

In addition, the radio-frequency signal (e.g., the antenna current) from the radiation portion **111** is coupled to the parasitic portion **112** and conducted to the ground plane **101** through the second isolation circuit **130**, such that the antenna element **110** may also generate at least one low-frequency resonant mode through the radiation portion **111** and the parasitic portion **112**. For example, in the embodiment of FIG. **1**, the radiation portion **111** and the parasitic portion **112** may form a first low-frequency resonance path, and the parasitic portion **112** itself may from a second low-frequency resonance path. Therefore, the antenna element **110** may generate two low-frequency resonant modes through the radiation portion **111** and the parasitic portion **112**. Accordingly, the antenna element **110** may convert the radio-frequency signal into the electromagnetic wave, so as to accomplish a characteristic of multi-frequency operation.

In addition, the mobile communication device **100** may further utilize the antenna element **110** to sense whether an object (e.g., the human body) exists nearby, and adjust a radiation power of the antenna element **110** according to a sensing result. For example, the antenna element **110** is equivalent to one sensing electrode in which an initial capacitance changes when the human body is near. The sensing controller **190** detects changes in a capacitance. Further, when the human body is close to a specific distance, the sensing controller **190** detects a capacitance exceeding a set value and thereby generates a signal to the radio-frequency module for reducing an output power of the radio-frequency module. The first isolation circuit **120** and the high-frequency blocking element **140** transmit a sensing signal, and the second isolation circuit **130** and the low-frequency blocking element **150** block the sensing signal. In other words, for the sensing signal, the first isolation circuit **120** and the high-frequency blocking element **140** form a short circuit for transmitting the sensing signal, and the second isolation circuit **130** and the low-frequency blocking element **150** form a broken circuit (i.e., open circuit) for blocking the sensing signal from passing through.

Therefore, the radiation portion **111** and the parasitic portion **112** in the antenna element **110** may be regarded as a large sheet of metal plate to be further used as a sensing element (e.g., the sensing electrode) of the sensing controller **190**. The low-frequency blocking element **150** may be used to prevent a sensing function of the antenna element **110** from being influenced by the coaxial cable **180**. Furthermore, the high-frequency blocking element **140** may transmit the sensing signal from the antenna element **110** to the sensing controller **190** through the metal line **170**, and the sensing controller **190** may determine whether an object exists near the mobile communication device **100** according to the sensing signal. Accordingly, the mobile communication device **100** may adjust a transmit power of the radio-frequency module according to a determination result of the sensing controller **190**, so as to prevent the electromagnetic wave radiated by the antenna element **110** from endangering human health.

In other words, besides that the antenna element **110** includes the function of the wireless transmission, the antenna element **110** may also be used as the sensing element of the sensing controller **190**. It should be noted, in the present embodiment, the high-frequency blocking element **140** is disposed on the parasitic portion **112** of the antenna element **110**, such that a transmission path for connecting to the sensing controller **190** is extended from the parasitic portion **112** of the antenna element **110**. Accordingly, the present embodiment is capable of routing the metal line **170** for connecting to the sensing controller **190** from one side of the antenna element **110**. Therefore, the present embodiment is capable of reducing a length of the metal line **170** for connecting to the sensing controller **190**, or preventing the metal line **170** from being too close to the antenna element **110**, so as to reduce influences caused by the metal line **170** to the antenna element **110**.

It is worth mentioning that, the low-frequency blocking element **150** may be, for example, a capacitive element. A first terminal of said capacitive element is adjacent to the feeding point FP**1** and electrically connected to the radiation portion **111**, a second terminal of said capacitive element is electrically connected to an inner conductor of the coaxial cable **180**, and a capacitance of said capacitive element may be, for example, 15 pF. Further, the high-frequency blocking element **140** may be, for example, an inductive element, an inductance of said inductive element is greater than 120 nH, and the inductance may be adjusted according to actual situations.

Furthermore, the first isolation circuit **120** includes an inductive element **121** and an inductive element **122**. A first terminal of the inductive element **121** is electrically to the parasitic portion **112**, and a second terminal of the inductive element **121** is electrically connected to the connection element **160**. Further, a first terminal of the inductive element **122** is electrically connected to the connection element **160**, and a second terminal of the inductive element **122** is electrically connected to the radiation portion **111**. Accordingly, the first isolation circuit **120** may block the radio-frequency signal (e.g., the antenna current) and transmit the sensing signal through the inductive elements **121** and **122**.

Although FIG. **1** illustrates an implementation pattern of the first isolation circuit **120**, the invention is not limited thereto. For instance, in another embodiment, the first isolation circuit **120** may only include one of the inductive elements **121** and **122**, and the included inductive element **121** (or **122**) may also be connected in series with the connection element **160**. That is, in another embodiment, the first isolation circuit **120** includes an inductive element, and said inductive element and the connection element **160** are connected in series between the radiation portion **111** and the parasitic portion **112**.

Furthermore, the second isolation circuit **130** includes a capacitive element **131** and an inductive element **132**. A first terminal of the capacitive element **131** is electrically connected to the parasitic portion **112**. In addition, a first terminal of the inductive element **132** is electrically connected a second terminal of the capacitive element **131**, and a second terminal of the inductive element **132** is electrically connected to the ground plane **101**. Accordingly, the second isolation circuit **130** may block the sensing signal and transmit the radio-frequency signal through the capacitive element **131** and the inductive element **132**.

FIG. **2** is a schematic structural view illustrating a mobile communication device according to another embodiment of the invention. As shown in FIG. **2**, a mobile communication device **200** includes an antenna element **210**, an isolation circuit **220**, a first high-frequency blocking element **230**, a second high-frequency blocking element **240** and a low-frequency blocking element **250**. The antenna element **210** includes a radiation portion **211** and a parasitic portion **212**.

The radiation portion **211** has a feeding point FP**2**, and the radiation portion **211** and the parasitic portion **212** are spaced by a coupling gap D**2**. In addition, the isolation circuit **220** is electrically connected between the parasitic portion **212** and a ground plane **201**. The first high-frequency blocking element **230** is electrically connected between the parasitic portion **212** and a first metal line **271**. The second high-frequency blocking element **240** is electrically connected between the radiation portion **211** and a second metal line **272**. The low-frequency blocking element **250** is electrically connected to the radiation portion **211**.

In operation, the antenna element **210** may convert a radio-frequency signal into an electromagnetic wave, so that the mobile communication device **200** may perform a wireless transmission through the antenna element **210**. For instance, in an embodiment, the radiation portion **211** is electrically connected to a coaxial cable **280** through the low-frequency blocking element **250**. The coaxial cable **280** is configured to transmit the radio-frequency signal generated by a radio-frequency module. In addition, the low-frequency blocking element **250** receives the radio-frequency signal from the coaxial cable **280**, and transmits the radio-frequency signal to the feeding point FP**2** of the radiation portion **211**. Furthermore, the radio-frequency signal of the radiation portion **211** is coupled to the parasitic portion **212** by the coupling gap D**2**.

It should be noted that, for the radio-frequency signal, the isolation circuit **220** forms a short circuit for transmitting the radio-frequency signal, and the first high-frequency blocking element **230** and the second high-frequency blocking element **240** form a broken circuit (i.e., open circuit) for blocking the radio-frequency signal from passing through. Accordingly, as similar to the embodiment of FIG. **1**, the radiation portion **211** generates at least one high-frequency resonant mode under excitation of the radio-frequency signal. In addition, the radio-frequency signal from the radiation portion **211** is coupled to the parasitic portion **212**, such that the antenna element **210** may also generate at least one low-frequency resonant mode through the radiation portion **211** and the parasitic portion **212**. Accordingly, the antenna element **210** may convert the radio-frequency signal into the electromagnetic wave, so as to accomplish a characteristic of multi-frequency operation.

In addition, the mobile communication device **200** may further utilize the antenna element **210** to sense whether an object exists nearby, and adjust a radiation power of the antenna element **210** according to a sensing result. For example, the parasitic portion **212** generates a first sensing signal in response to a proximity of an object. On the other hand, the radiation portion **211** also generates a second sensing signal in response to the proximity of the object. For the first sensing signal, the isolation circuit **220** forms a broken circuit (i.e., open circuit) for blocking the first sensing signal from passing through. In addition, the first high-frequency blocking element **230** forms a short circuit and transmits the first sensing signal to a first sensing controller **291** through the first metal line **271**. On the other hand, for the second sensing signal, the second high-frequency blocking element **240** forms a short circuit and transmits the second sensing signal to a second sensing controller **292** through the second metal line **272**.

In other words, the parasitic portion **212** is equivalent to a sensing element of the first sensing controller **291**, and the radiation portion **211** is equivalent to a sensing element of the second sensing controller **292**. The low-frequency blocking element **250** may be used to prevent a sensing function of the radiation portion **211** from being influenced by the coaxial cable **280**. On the other hand, the first sensing controller **291** and the second sensing controller **292** may determine whether an object exists near the mobile communication device **200** according to sensing results of the parasitic portion **212** and the radiation portion **211**. In addition, the mobile communication device **200** adjusts a transmit power of the antenna element **210** according to determination results of the first sensing controller **291** and the second sensing controller **292**, so as to prevent the electromagnetic wave radiated by the antenna element **210** from endangering human health.

Specifically, besides that the antenna element **210** includes the function of the wireless transmission, the antenna element **210** may also be used as the sensing elements of the two sensing controllers **291** and **292**. It should be noted, in the present embodiment, transmission paths for connecting to the two sensing controllers **291** and **292** are extended from the radiation portion **211** and the parasitic portion **212**, respectively. Accordingly, the present embodiment is capable of routing the two metal lines **271** and **272** for connecting to the two sensing controllers **291** and **292** respectively from two sides of the antenna element **210**. Therefore, the present embodiment is capable of reducing lengths of the two metal lines **271** and **272**, or preventing the two metal lines **271** and **272** from being too close to the antenna element **210**, so as to reduce influences caused by the two metal lines **271** and **272** to the antenna element **210**.

Furthermore, the isolation circuit **220** includes a capacitive element **221** and an inductive element **222**. A first terminal of the capacitive element **221** is electrically connected to the parasitic portion **212**. In addition, a first terminal of the inductive element **222** is electrically connected a second terminal of the capacitive element **221**, and a second terminal of the inductive element **222** is electrically connected to the ground plane **201**. Accordingly, the isolation circuit **220** may block the first sensing signal and transmit the radio-frequency signal through the capacitive element **221** and the inductive element **222**.

It is worth mentioning that, although the foregoing embodiment illustrates an implementation pattern of the radiation element, the invention is not limited thereto. Persons of ordinary skill in the art may dispose an extending segment in the antenna element based on design requirements, so as to increase operation bands of the antenna element. For instance, FIG. **3** and FIG. **4** are schematic structural views respectively illustrating an antenna element according to an embodiment of the invention In comparison with the antenna element **110** of FIG. **1**, a parasitic portion **312** in an antenna element **310** of FIG. **3** further includes an extending segment **320**, and a parasitic portion **412** in an antenna element **410** of FIG. **4** further includes an extending segment **420**. Accordingly, the parasitic portion **312** may also utilize the extending segment **320** to generate a high-frequency resonance path, so as facilitate in expanding the operation bands for the antenna element **310**. Similarly, the antenna element **410** may also expand the operation bands thereof through the extending segment **420**.

In summary, in addition to the function of the wireless transmission, the antenna element of the invention may also be used as the sensing element of the sensing controller. In addition, the high-frequency blocking element is further disposed on the parasitic portion of the antenna element in the invention, such that the metal line for connecting to the sensing controller may be routed from at least one side of the antenna element. Accordingly, the length of the metal line for connecting to the sensing controller may be reduced, or the metal line may be prevented from being too close to the antenna element, so as to reduce influences caused by the metal line to the antenna element.

Although the present disclosure has been described with reference to the above embodiments, it will be apparent to one of ordinary skill in the art that modifications to the described embodiments may be made without departing from the spirit of the present disclosure. Accordingly, the scope of the present disclosure will be defined by the attached claims and not by the above detailed descriptions.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A mobile communication device, comprising:
- an antenna element, converting a radio-frequency signal into an electromagnetic wave and generating a sensing signal in response to a proximity of an object, and the antenna element comprising a radiation portion and a parasitic portion which are spaced by a coupling gap;
- a low-frequency blocking element, electrically connected to the radiation portion, and the low-frequency blocking element receiving the radio-frequency signal and transmitting the radio-frequency signal to a feeding point of the radiation portion;
- a first isolation circuit, connected to a connection element in series between the radiation portion and the parasitic portion, and the first isolation circuit being configured to block the radio-frequency signal and transmit the sensing signal;
- a second isolation circuit, electrically connected between the parasitic portion and a ground plane, and the second isolation circuit being configured to block the sensing signal and transmit the radio-frequency signal; and
- a high-frequency blocking element, electrically connected between the parasitic portion and a metal line, and transmitting the sensing signal from the antenna element to a sensing controller through the metal line.

2. The mobile communication device of claim **1**, wherein the first isolation circuit comprises:
- a first inductive element, having a first terminal electrically connected to the parasitic portion and a second terminal electrically connected to the connection element; and
- a second inductive element, having a first terminal electrically connected to the connection element and a second terminal electrically connected to the radiation portion.

3. The mobile communication device of claim **1**, wherein the first isolation circuit comprises an inductive element, and the inductive element and the connection element are connected in series between the radiation portion and the parasitic portion.

4. The mobile communication device of claim **1**, wherein the second isolation circuit comprises:

a capacitive element, having a first terminal electrically connected to the parasitic portion; and

an inductive element, having a first terminal electrically connected a second terminal of the capacitive element and a second terminal electrically connected to the ground plane.

5. The mobile communication device of claim **1**, wherein the low-frequency blocking element is a capacitive element, a first terminal of the capacitive element is adjacent to the feeding point and electrically connected to the radiation portion, and a second terminal of the capacitive element is electrically connected to an inner conductor of a coaxial cable.

6. The mobile communication device of claim **1**, wherein the high-frequency blocking element is an inductive element.

7. The mobile communication device of claim **1**, wherein when the radio-frequency signal is received by the antenna element, the antenna element generates at least one high-frequency resonant mode through the radiation portion, and generates at least one low-frequency resonant mode through the radiation portion and the parasitic portion.

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